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Keystone Reservoir, Tulsa, Osage, Creek and Pawnee Counties, Oklahoma

National Eutrophication Survey, Las Vegas, Nev

Prepared for

Environmental Monitoring and Support Lab, Las Vegas, Nev

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16 ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

KEYSTONE RESERVOIR

TULSA, OSAGE, CREEK AND

PAWNEE COUNTIES

OKLAHOMA

EPA REGION VI

WORKING PAPER NO. 501

WITH THE COOPERATION OF THE

OKLAHOMA DEPARTMENT OF POLLUTION CONTROL

AND THE

OKLAHOMA NATIONAL GUARD

MARCH, 1977

REPORT ON KEYSTONE RESERVOIR

TULSA, OSAGE, CREEK AND PAWNEE COUNTIES, OKLAHOMA

EPA REGION VI

by

National Eutrophication Survey

Water and Land Monitoring Branch
Monitoring Applications Laboratory
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Eutrophication Survey Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

Working Paper No. 591

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March 1977

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Oklahoma Department of Pollution Control for professional involvement, to the Oklahoma National Guard for conducting the tributary sampling phase of the Survey, and to those Oklahoma wastewater treatment plant operators who provided effluent samples and flow data.

Dr. Denver Talley, Director, Oklahoma Department of Pollution Control; the staff of the Oklahoma Water Resources Board; and the staff of the Oklahoma State Department of Health reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper Series.

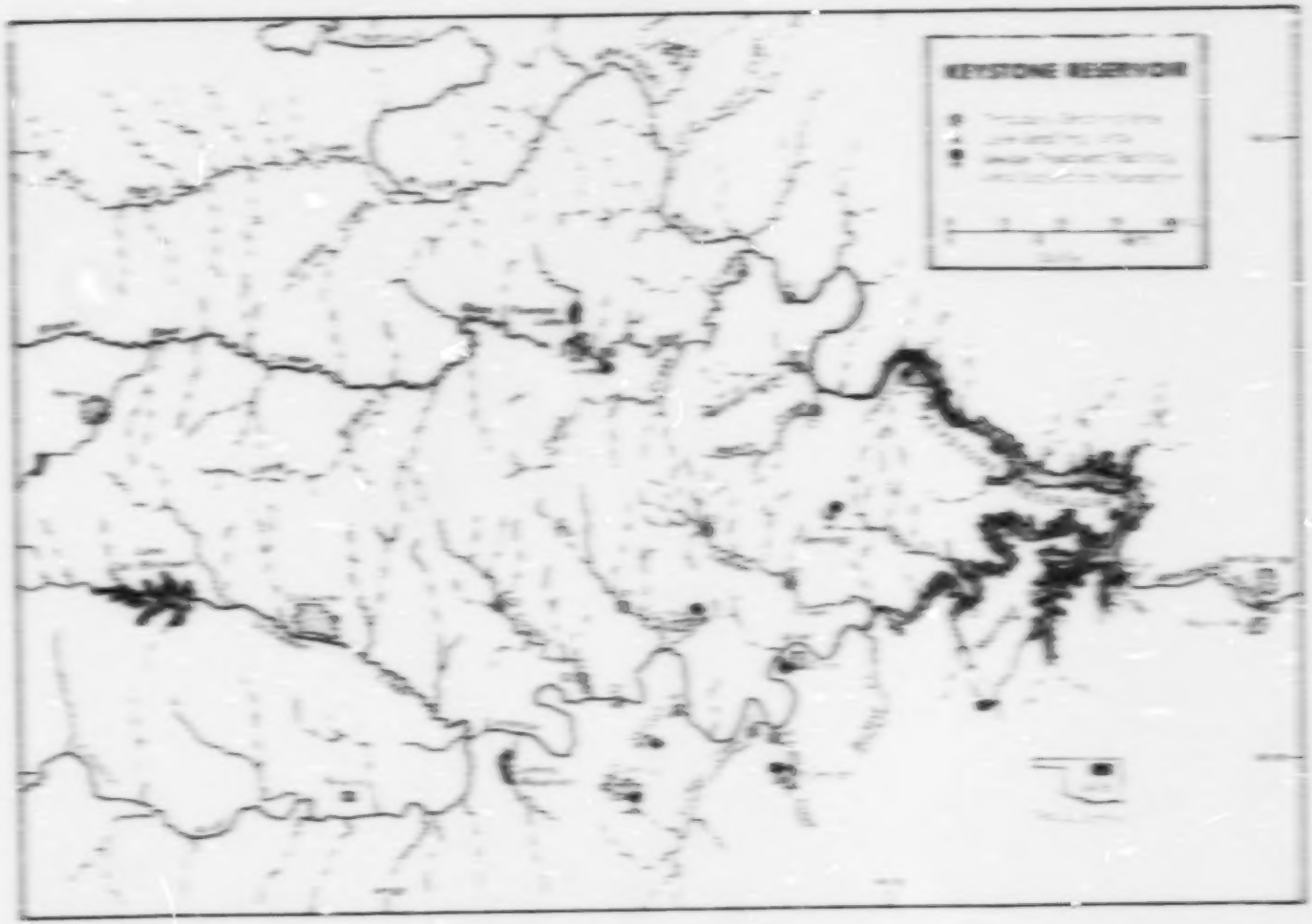
Major General John Coffey, Jr., the Adjutant General of Oklahoma, and Project Officers Colonel Curtis W. Milligan and Major James O. Haney, Jr., who directed the volunteer efforts of the Oklahoma National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF OKLAHOMA

LAKE NAME	COUNTY
Altus Reservoir	Greer, Kiowa
Arbuckle Lake	Murray
Lake Elsworth	Caddo, Comanche
Lake Eufaula	Haskell, McIntosh, Okmulgee, Pittsburg
Fort Cobb Reservoir	Caddo
Fort Supply Reservoir	Woodward
Foss Dam Reservoir	Custer
Lake Frances	Adair
Grand Lake O' The Cherokees	Mayes, Delaware, Craig, Ottowa
Lake Hefner	Oklahoma
Keystone Reservoir	Tulsa, Creek, Osage, Pawnee
Ootogah Lake	Nowata, Rogers
Tenkiller Ferry Reservoir	Cherokee, Sequoyah
Lake Thunderbird	Cleveland
Wister Reservoir	Leflore


KEYSTONE RESERVOIR

REPORT ON KEYSTONE RESERVOIR, OKLAHOMA
STORET NO. 4011

I. CONCLUSIONS

A. Trophic Condition:*

On the basis of field observations and Survey data, Keystone Reservoir is considered eutrophic, i.e., nutrient rich and highly productive. Whether such nutrient enrichment is to be considered beneficial or deleterious is determined by its actual or potential impact upon designated beneficial water uses of each lake.

Chlorophyll a values in the lake ranged from 0.3 ug/l in June to 181.1 ug/l in October, with a mean of 21.4 ug/l. Potential primary productivity as measured by algal assay control yield was extremely high, and Secchi disc visibility was low. Of the 16 Oklahoma lakes (including Lake Texoma) sampled in 1974, only 1 had higher median total phosphorus levels, 2 had higher median inorganic nitrogen values and none had higher median orthophosphorus levels than Keystone Reservoir.

Survey limnologists did not observe any problem algal blooms or aquatic macrophytes during their visits to the lake. However, it was reported that the lake was highly

*See Appendix E.

turbid, and the low Secchi disc readings (range of 0.03 to 0.9 meters) suggest that primary productivity may be light limited in Keystone Reservoir.

B. Rate-Limiting Nutrient:

The algal assay results indicate that nitrogen was the primary limiting nutrient in Keystone Reservoir at the times of assay sample collections (04/03/74, 10/22/74). The lake data also indicate that nitrogen could limit production during all sampling times. However, low light penetration in most reaches of the lake is probably a more important controlling factor than the nutrient levels.

C. Nutrient Controllability:

1. Point sources -

The mean annual phosphorus load from point sources identified within 40 stream-km (25 miles) of Keystone Reservoir was estimated to be 1.3% of the total lake phosphorus load. The city of Cushing contributed 0.5% from two wastewater treatment plants, Cleveland contributed 0.3%, and six other municipal plants contributed a combined 0.5% of the total.

The present overall phosphorus loading rate of 16.40 g $P/m^2/yr$ is about 12 times that proposed by Vollenweider (1975) as "eutrophic" for lakes with such volume and

hydraulic retention time. On the basis of survey data it is expected that the trophic condition of Keystone Reservoir will continue to deteriorate if the present loading rate is maintained.

2. Nonpoint sources -

The mean annual phosphorus load not attributable to nearby point sources was about 98.7% of the total reaching the lake. The Arkansas River accounted for 75.7% of the total phosphorus load, the Cimarron River 21.4%, and the ungaged drainage areas were estimated to have contributed 1.4%. Included in the Arkansas and Cimarron River loadings undoubtedly are discharges of nutrient rich domestic and industrial wastes upstream from Keystone Reservoir which influence the lake. Examination of land use practice and identification of additional point sources may provide answers to further nutrient reductions in Keystone Reservoir.

The nonpoint phosphorus exports of the tributaries to Keystone Reservoir (Section IV-D) range from 4-11 kg P/km^2/yr. These exports are quite comparable to the unimpacted tributary exports of nearby Grand Lake o' the Cherokees* (range from 6-12 kg P/km^2/yr).

*See Working Paper No. 589, "Report on Grand Lake o' the Cherokees".

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake surface area and mean depth were provided by the Oklahoma Department of Pollution Control; maximum depth was provided by the Oklahoma Water Resources Board. Tributary flow data were provided by the Oklahoma District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 106.43 km^2.
2. Mean depth: 7.7 meters.
3. Maximum depth: 22.2 meters.
4. Volume: 819.511 x 10^6 m^3.
5. Mean hydraulic retention time: 55 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area(km²)	Mean Flow (m³/sec)
A-2 Arkansas River	123,624.0	130.40
B-1 Hellroaring Creek	27.7	0.08
D-1 Cimarron River	34,900.2	34.37
E-1 Lagoon Creek	123.3	0.46
Minor tributaries and immediate drainage -	3,991.0	14.43
Totals	162,667.0	179.73

2. Outlet - A-1 Arkansas River 162,673.4 173.81

C. Precipitation:

1. Year of sampling: 126.4 cm.
2. Mean annual: 91.6 cm.

III. LAKE WATER QUALITY SUMMARY

Keystone Reservoir was sampled four times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from 11 stations on the lake* and from a number of depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll a analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths (expressed in meters) sampled are listed below:

Station Number	Maximum Depth
01	9.4
02	7.9
03	19.8
04	15.8
05	17.1
06	12.2
07	6.4
08	7.3
09	16.8
10	23.2
11	7.6

For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the

*Stations 01, 02, and 07 were sampled only three times. At the June sampling, Station 10 replaced Station 03, and Station 11 replaced Station 08.

maximum depth for each site. Results of the phytoplankton counts and chlorophyll a determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

KEYSTONE RESERVOIR
STORET CODE 4022

PHYSICAL AND CHEMICAL CHARACTERISTICS

PARAMETER	N*	([illegible]) S*** = 6 RANGE	MEDIAN	MAX DEPTH RANGE (METERS)
TEMPERATURE (DEG CENT)				
0.-1.5 M DEPTH	6	[illegible]	[illegible]	0.0- 0.0
MAX DEPTH**	6	[illegible]	[illegible]	[illegible]
DISSOLVED OXYGEN (MG/L)				
0.-1.5 M DEPTH	6	[illegible]	[illegible]	0.0- 0.0
MAX DEPTH**	6	[illegible]	[illegible]	[illegible]
CONDUCTIVITY (UMHOS)				
0.-1.5 M DEPTH	6	[illegible]	[illegible]	0.0- 0.0
MAX DEPTH**	6	[illegible]	[illegible]	[illegible]
PH (STANDARD UNITS)				
0.-1.5 M DEPTH	6	[illegible]	[illegible]	0.0- 0.0
MAX DEPTH**	6	[illegible]	[illegible]	[illegible]
TOTAL ALKALINITY (MG/L)				
0.-1.5 M DEPTH	5	[illegible]	[illegible]	0.0- 0.0
MAX DEPTH**	5	[illegible]	[illegible]	[illegible]
TOTAL P (MG/L)				
0.-1.5 M DEPTH	5	[illegible]	[illegible]	0.0- 0.0
MAX DEPTH**	5	[illegible]	[illegible]	[illegible]
DISSOLVED ORTHO P (MG/L)				
0.-1.5 M DEPTH	5	[illegible]	[illegible]	0.0- 0.0
MAX DEPTH**	5	[illegible]	[illegible]	[illegible]
NO2+NO3 (MG/L)				
0.-1.5 M DEPTH	5	[illegible]	[illegible]	0.0- 0.0
MAX DEPTH**	5	[illegible]	[illegible]	[illegible]
AMMONIA (MG/L)				
0.-1.5 M DEPTH	5	[illegible]	[illegible]	0.0- 0.0
MAX DEPTH**	5	[illegible]	[illegible]	[illegible]
KJELDAHL N (MG/L)				
0.-1.5 M DEPTH	5	[illegible]	[illegible]	[illegible]
MAX DEPTH**	5	[illegible]	[illegible]	[illegible]
SECCHI DISC (METERS)				
	6	[illegible]	[illegible]	

* N = NO. OF SAMPLES
** MAXIMUM DEPTH SAMPLED AT EACH SITE
*** S = NO. OF SITES SAMPLED ON THIS DATE

B. Biological Characteristics

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/02/74	1. Centric diatoms	2,146
	2. Chroomonas	503
	3. Chrysophytan cell	450
	4. Ankistrodesmus	265
	5. Nitzschia	264
	Other genera	797
	total	4,425
06/12/74	1. Chroomonas	344
	2. Cryptomonas	238
	3. Cyclotella	106
	4. Chlamydomonas	53
	5. Skeletonema	53
	Other genera	[illegible]
	total	794
08/29/74	1. Centric diatoms	1,086
	2. Chrysophytan cell	126
	3. Navicula	51
	4. Chlamydomonas	51
	5. Chroomonas	25
	Other genera	303
	total	1,642
10/21/74	1. Skeletonema	4,551
	2. Chlamydomonas	3,519
	3. Cyclotella	2,074
	4. Ankistrodesmus	461
	5. Chrysophytan cell	295
	Other genera	1,234
	total	12,934

F. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
04/02/74	01	8.2
	02	21.7
	03	3.2
	04	11.5
	05	11.0
	06	3.1
	07	50.2
	08	71.1
	09	6.6
	10	---
	11	---
06/12/74	01	1.6
	02	1.9
	03	---
	04	1.6
	05	0.3
	06	1.5
	07	2.6
	08	---
	09	0.8
	10	0.4
	11	4.4

2. Chlorophyll a - (continued)

Sampling Date	Station Number	Chlorophyll a (ug/l)
08/29/74	01	-
	02	-
	03	-
	04	4.8
	05	3.0
	06	3.9
	07	-
	08	10.9
	09	2.3
	10	1.4
	11	-
10/23/74	01	25.1
	02	46.6
	03	-
	04	10.4
	05	12.4
	06	20.5
	07	164.9
	08	-
	09	1.5
	10	9.6
	11	161.1

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike(mg/l)	Ortho P Conc.(mg/l)	Inorganic N Conc.(mg/l)	Maximum Yield (mg/l-dry wt.)
a. 04/03/74 (Stations 01-02)			
Control	0.030	0.116	17.9
0.05 P	0.080	0.116	17.6
0.05 P + 1.0 N	0.080	1.116	27.6
1.00 N	0.030	1.116	17.6
(Stations 03-05)			
Control	0.090	0.730	16.6
0.05 P	0.140	0.730	19.5
0.05 P + 1.0 N	0.140	1.730	31.2
1.00 N	0.090	1.730	26.1
(Stations 06-09)			
Control	0.100	0.663	17.2
0.05 P	0.150	0.663	19.7
0.05 P + 1.0 N	0.150	1.663	33.8
1.00 N	0.100	1.663	23.8
b. 10/22/74 (Stations 02, 06, 07, 11)			
Control	0.173	0.161	4.9
0.05 P	0.223	0.161	4.8
0.05 P + 1.0 N	0.223	1.161	25.2
1.00 N	0.173	1.161	24.3

F. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity was extremely high in Keystone Reservoir during the sampling year. In the spring assays for Stations 03-09, and in the autumn assay, the addition of nitrogen alone produced a significant increase in yield over that of the control, indicating those samples were nitrogen limited. However, the very modest control yield in the autumn sample, relative to the high levels of macronutrients available, suggest that an additional factor(s) complicates the growth limitation picture. In the spring assay for Stations 01-02, no increase in yield was observed with the addition of either phosphorus or nitrogen alone, but the simultaneous addition of both nutrients produced a significant increase, suggesting colimitation by the two nutrients.

The mean inorganic nitrogen to orthophosphorus (N/P) ratios in the lake data were 7/1 or less on all sampling occasions, further indicating primary limitation by nitrogen (a mean N/P ratio of 14/1 or greater generally reflects phosphorus limitation). Comparisons of light penetration values and corresponding chlorophyll a levels (positive relationship) strongly suggest that the latter are controlled by, rather than control, the high turbidity in this lake.

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Oklahoma National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v). Sampling was begun in November 1974, and was completed in October 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Oklahoma District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in kg/km^2/year in Hellroaring Creek and Lagoon Creek at Stations B-1 and E-1 and multiplying the means by the ZZ area in km^2.

The operators of the Drumright and Cushing (south) wastewater treatment plants provided monthly effluent samples and corresponding flow data. Nutrient loads for the Cushing (north), Oilton, Yale, Jennings, Mannford, Cleveland (2 plants) and Pawnee

wastewater treatment plants were estimated at 1.134 kg P and 3.401 kg N/capita/year.

A. Waste Sources:

1. Known municipal -

Name	Pop.* Served	Treatment*	Mean Flow ($m^3/d \times 10^3$)	Receiving Water
Drumright	3,000	Trickling filter	0.806	Cimerron River
Cushing (south)	7,000	Trickling filter	2.740	Cottonwood Creek/ Euchee Creek
Cushing (north)	4,175	Trickling filter	1.580**	Skull Creek
Oilton	1,260	Stabilization pond	0.477**	Cimarron River
Yale	1,300	Stabilization pond	0.492**	Mud Creek/ Cimarron River
Jennings	338	Primary septic	0.128	Horse Creek/ Keystone Reservoir
Mannford	1,000	Stabilization pond	0.378**	Salt Creek
Cleveland North	3,000	Stabilization pond	1.136**	Keystone Reservoir
Cleveland South	1,000	Stabilization pond	0.378**	Keystone Reservoir
Pawnee	2,500	Trickling filter	0.946**	Black Bear Creek

2. Known industrial -

Name	Product	Treatment	Mean Flow ($m^3/d \times 10^3$)	Receiving Water
Dalton Precision (Cushing)	Iron foundry	?	?	Eucha Creek
Cushing Tank Car	Railroad equipment	?	?	Skull Creek

*Provided by plant operators and/or U.S.EPA, 1971.
**Estimated at 0.3785 m^3/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 Arkansas River	1,327,465	75.7
B-1 Hellroaring Creek	105	<0.1
D-1 Cimarron River	376,215	21.5
E-1 Lagoon Creek	980	<0.1
b. Minor tributaries and immediate drainage (nonpoint load)	23,945	1.4
c. Known municipal STP's -		
Drumright	2,670	0.1
Cushing (north)	4,735	0.3
Cushing (south)	3,565	0.2
Oilton	1,430	0.1
Yale	1,475	0.1
Jennings	385	<0.1
Mannford	1,135	0.1
Cleveland North	3,400	0.2
Cleveland South	1,135	0.1
Pawnee	2,835	0.1
d. Septic tanks* -	10	<0.1
e. Known industrial -		
Dalton Precision (Cushing)	unknown	
Cushing	unknown	
f. Direct precipitation** -	1,860	0.1
Totals	1,753,845	100.0
2. Output - A-1 Arkansas River	785,740	
3. Net annual P accumulation	968,105	

*Estimate based on 34 lakeshore residences and 1 park.
**Estimated (see NES Working Paper No. 175).

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 Arkansas River	11,314,805	79.2
B-1 Hellroaring Creek	3,485	<0.1
D-1 Cimarron River	2,205,805	15.4
E-1 Lagoon Creek	19,510	0.1
b. Minor tributaries and immediate drainage (nonpoint load) -	566,720	4.0
c. Known municipal STP's -		
Drumright	5,390	<0.1
Cushing (north)	14,200	0.1
Cushing (south)	9,010	0.1
Oilton	4,255	<0.1
Yale	6,420	<0.1
Jennings	1,150	<0.1
Mannford	3,400	<0.1
Cleveland North	10,205	0.1
Cleveland South	3,400	<0.1
Pawnee	8,500	0.1
d. Septic tanks* -	395	<0.1
e. Known industrial -		
Dalton Precision (Cushing)	unknown	
Cushing Tank Car	unknown	
f. Direct precipitation** -	114,900	0.8
Totals	14,289,580	100.0
2. Outputs - A-1 Arkansas River	8,746,810	
3. Net annual N accumulation	5,542,770	

*Estimated based on 34 lakeshore residences and 1 park.
**Estimated (see NES Working Paper No. 175).

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Arkansas River	11	92
Hellroaring Creek	4	126
Cimarron River	11	63
Lawson Creek	8	158

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P (mg/l)	Mean Total N (mg/l)
C-1 Ranch Creek	0.069	1.345
F-1 Salt Creek	0.080	1.068
G-1 Council Creek	0.071	1.182
H-1 Tiger Creek	0.397	1.672
J-1 Euchee Creek	0.160	1.253
K-1 Skull Creek	0.142	8.059

Nutrient loadings for Tiger Creek (H-1), Euchee Creek (J-1), and Skull Creek (K-1) are substantially higher than the other tributaries leading to Keystone Reservoir, due to the impact of municipal and industrial sewage treatment facilities in the towns of Drumright and Cushing.

F. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his "eutrophic" loading is that at which the receiving waters would become eutrophic or remain eutrophic; his "oligotrophic" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A "mesotrophic" loading would be considered one between "eutrophic" and "oligotrophic".

Note that Vollenweider's model may not be applicable to water bodies with very short retention times or in which light penetration is severely restricted from high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for Keystone Reservoir	16.48
Vollenweider's "eutrophic" loading	1.36
Vollenweider's "oligotrophic" loading	0.68

V. LITERATURE REVIEWED

U.S. Environmental Protection Agency. 1971. "Inventory of Wastewater Treatment Facilities". EPA Publication No. OWP-1, Volume 6. Office of Media Programs, Office of Water Programs, Washington, D.C.

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey Methods 1973-1976. Working Paper No. 175. National Environmental Research Center, Las Vegas, Nevada, and Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

Vollenweider, R. A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol. 37:53-84.

VI. APPENDICES

APPENDIX A
CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B
TRIBUTARY FLOW DATA

LAKE CODE [illegible] [illegible]

TOTAL DRAINAGE AREA OF LAKE(SQ MI) [illegible]

TRIBUTARY	SUB-DRAINAGE AREA(SQ MI)	NORMALIZED FLOWS(CFS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = [illegible]
TOTAL FLOW IN = [illegible]
SUM OF SUB-DRAINAGE AREAS = [illegible]
TOTAL FLOW OUT = [illegible]

MEAN MONTHLY FLOWS AND DAILY FLOWS(CFS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
[illegible]	11	74	[illegible]	2	[illegible]				
	12	74	[illegible]	[illegible]	[illegible]				
	1	75	[illegible]	[illegible]	[illegible]				
	2	75	[illegible]	[illegible]	[illegible]				
	3	75	[illegible]	[illegible]	[illegible]				
	4	75	[illegible]	[illegible]	[illegible]				
	5	75	[illegible]	[illegible]	[illegible]				
	6	75	[illegible]						
	7	75	[illegible]						
	8	75	[illegible]	7	[illegible]				
	9	75	[illegible]						
	10	75	[illegible]	[illegible]	[illegible]				
[illegible]	11	74	[illegible]	2	[illegible]	[illegible]	[illegible]		
	12	74	[illegible]	[illegible]	[illegible]				
	1	75	[illegible]	[illegible]	[illegible]				
	2	75	[illegible]	[illegible]	[illegible]				
	3	75	[illegible]	[illegible]	[illegible]				
	4	75	[illegible]	[illegible]	[illegible]				
	5	75	[illegible]	[illegible]	[illegible]				
	6	75	[illegible]						
	7	75	[illegible]	[illegible]	[illegible]				
	8	75	[illegible]	[illegible]	[illegible]				
	9	75	[illegible]						
	10	75	[illegible]	[illegible]	[illegible]				

[illegible]

APPENDIX C
PHYSICAL AND CHEMICAL DATA

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

APPENDIX D

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[illegible]

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1974

STATE OF OKLAHOMA

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